EFFECTS OF TYPES AND LEVELS OF FAT AND RATES AND TEMPERATURES OF COMMINUTION ON THE PROCESSING AND CHARACTERISTICS OF FRANKFURTERS

SUMMARY—Frankfurter emulsions containing either 25% or 35% beef fat, pork fat, or cottonseed oil were prepared by comminuting at 1500, 2500, or 5000 rpm to temperatures ranging from 45°–85°F. Data were obtained on the viscosities of the emulsions; except for initially high viscosities for which unmelted fat was responsible, the viscosities of emulsions containing the fats, or oil, were similar: viscosities tended to decrease with increasing time and temperature of chopping. The frankfurters were stuffed, smoked, and cooked, and data were obtained on shrinkage, fat retention, ease of peeling, specific gravity, and texture. Shrinkage was inversely related to content of fat. Fat separation mainly occurred in processing frankfurters containing beef fat; the data suggest that emulsions containing beef fat should be comminuted to 65°–75°F to avoid possible under or overchopping: the results show that optimum conditions were time as well as temperature dependent. The air content of frankfurters varied inversely with the maximum temperature attained during comminution. Frankfurter skin strength was lessened on increasing the temperatures to which emulsions were comminuted; elasticity, the equivalent of rubberiness, decreased under these conditions.

INTRODUCTION

THE SCIENCE of meat emulsions has been referred to as one of the youngest areas in food science (Saffle, 1968). It is because of this, and not any lack of recent effort, that research on many factors involved in the production of emulsion-based products is lacking or incomplete. Priority has been given to solving the problem of producing emulsions which can be heat processed during production and possibly reheated by consumers without loss of fat. Meat proteins have been identified as emulsion stabilizers and factors affecting this function established as detailed recently in a review by Saffle (1968).

On the other hand, while the properties of meat fats are known to affect emulsification, the effect of variations on emulsion stability and processing requirements are not well understood. Results of earlier work of Townsend et al. (1968a; 1968b) suggested that the melting characteristics of meat fats could be the basis for differences in the maximum temperatures at which meat formulas should be emulsified. In later work the stability of emulsions of two series of fractionated beef and pork fats was studied with results suggesting that the melting characteristics of fats, rates and extent of temperature rise, and rates of dispersion (shear forces) interrelate in determining emulsion stability (Swift et al., 1968).

Subsequently, to obtain additional information on this relationship, an investigation of the effect of varying formulas and processing on emulsion and frankfurter characteristics was undertaken. Emulsions containing 25% or 35% beef fat, pork fat, or cottonseed oil and chopped at 1500, 2500, or 5000 rpm to temperatures ranging from 45°–85°F were prepared, stuffed, and then smoked and cooked. The effects on the time required in chopping, viscosity of emulsions, and the shrinkage, peeling characteristics, specific gravity and texture of frankfurters are reported in this paper.

EXPERIMENTAL

Materials and formulas

Two Commercial grade beef and eight market weight hog carcasses were stored at 37°F for from 3–5 days after slaughter. All tissues from the carcasses were removed and separated into distinctly lean and fat portions after which the lots of lean beef, beef tissue fat, lean pork, and pork tissue fat were cut into pieces several cubic inches in size (no internal fats, i.e., kidney, caul, or ruffle fats, were used). After each lot was thoroughly mixed, samples were removed for analyses and approximately 12.5-lb portions were stored under vacuum in Cry-O-Vac bags at 0°F. A winterized cottonseed oil was stored at 37°–38°F. Based on the results of analyses of raw materials, formulas designed to produce frankfurters containing approximately 9–10% added moisture and either 25% or 35% fat were calculated (Table 1).

Appropriate quantities of frozen fat and lean meat were removed from the freezer 2 days before each experiment and allowed to partially thaw. Lean meats were ground once through a 3/16-in plate and tissue fat once through a 1/2-in plate in a room maintained at 55°F and comminuted immediately thereafter. Cottonseed oil was used immediately upon withdrawal from a 37°–38°F cooler. The weight of lean beef, lean pork, and fats, or oil, in each batch comminuted was 50 lb to which were added appropriate weights of ice and a curing and spice mixture which provided 2.5 lb NaCl, 0.25 oz $NaNO_2$, 2 oz $NaNO_3$, 0.86 oz Na ascorbate, 1.98 lb cane sugar, and 8.5 oz of commercial spices per 100 lb meat.

Table 1—Formulas comminuted and the composition of finished frankfurters.

Series no.	Fat: Approx. content %	Fat: Type[1]	Emulsification rpm	Meat[2]: Lean beef %	Meat[2]: Lean pork %	Fat or oil %	Ice lb/100 lb meat	Composition of frankfurters[3]: Moisture %	Fat %	Protein %	Added moisture %
1	25	BF	1500	46	20	34	32	57.6	25.7	12.3	8.4
2	35	BF	1500	42	12	46	27	50.4	34.0	10.9	6.8
3	25	BF	2500	46	20	34	33	56.8	25.6	12.5	6.8
4	35	BF	2500	42	11	47	30	49.4	34.2	10.7	6.6
5	25	BF	5000	46	20	34	33	56.8	25.8	12.8	5.5
6	35	BF	5000	42	12	46	27	49.5	34.5	11.3	4.3
7	25	PF	1500	45	25	30	28	57.1	25.8	12.8	5.9
8	35	PF	1500	46	10	44	25	49.3	34.6	10.8	6.1
9	25	PF	2500	45	25	30	28	55.9	25.9	12.7	5.1
10	35	PF	2500	46	10	44	25	48.5	35.6	10.4	6.9
11	25	PF	5000	45	25	30	28	55.6	26.7	12.4	6.0
12	35	PF	5000	46	10	44	25	49.3	35.0	10.7	6.5
13	25	CO	1500	46	27	27	34	55.6	25.9	12.9	4.0
14	35	CO	1500	52	11	37	26	47.1	34.9	11.2	2.4
15	25	CO	2500	46	27	27	34	55.8	26.9	12.6	5.4
16	35	CO	2500	48	12	40	30	48.6	35.8	10.8	5.4
17	25	CO	5000	46	27	27	34	55.4	27.2	12.5	5.4
18	35	CO	5000	52	11	37	26	49.3	34.0	11.1	4.9

[1] Type of fat or oil. BF – beef fat; PF – pork fat; CO – cottonseed oil.
[2] 5.2 lb cure and spices added per 100 lb meat.
[3] Mean of analyses on all lots of each series.

[1] Present address: USDA, Richard B. Russell Agricultural Research Center, ARS, P.O. Box 5677, Athens, Georgia 30604.

Table 2–continued

ies o.	Oil content %	Emulsification Rpm	Emulsification Temp. °F	Smoking-cooking Shrinkage[1] %	Smoking-cooking Fat separation[2,3]	Peel-ability[2,4]	Specific gravity[5]
				Cottonseed oil			
13	25	1500	45		0	E	1.009 a b
			55	12.9 ± 0.4	0	E	1.005 b
			65		0	E	1.012 a
			74		0	E	1.015 a
14	35	1500[6]	45		0	G +	0.991 a
			55	9.4 ± 0.8	0	G +	1.001 a b
			65		0	G +	1.006 a b
			69		0	G +	1.008 b
15	25	2500	45		0	E	0.995 a
			55	12.8 ± 0.1	0	E	0.993 a
			65		0	E	1.001 b
			75		0	E	1.009 c
			85		0	E	1.011 b c
16	35	2500	45		0	E	1.004 a
			55		0	E	1.005 a
			65	10.0 ± 0.4	0	E	1.004 a
			75		0	E	1.005 a
			85		0	E	1.009 a
17	25	5000	45		0	E	0.978 a
			55		0	E	0.987 a b
			65	13.1 ± 0.2	0	E	1.000 b c
			75		0	E	1.007 c
			85		0	G	1.006 c
18	35	5000	45		0	G +	0.974 a
			55		0	G –	0.989 a b
			65	9.4 ± 0.3	0	G –	0.998 b
			75		0	G –	1.001 b c
			85		0	P (W)	1.007 c

[1] Mean of percentages of shrinkage of all lots in each series ± standard deviation.
[2] Based on judgments on 55–65 frankfurters. (W) indicates wetting was necessary.
[3] Plus signs indicate relative frequency.
[4] E = excellent; G = good; P = poor.
[5] Any means within the same series with different letters following are significantly different from each other at the 5% level.
[6] Oil added in three portions as was necessary to avoid severe separation of fat.

ing from easy peeling (excellent) to difficult peeling (poor) which was observed as adhesions between casings and frankfurters.

The mean specific gravity of frankfurters in each lot was calculated from values obtained by weighing the water displaced by each of three to five weighed frankfurters. The mean specific gravity of frankfurters prepared from vacuum treated emulsions was determined similarly.

An Instron TT-B floor model was used in determining the skin strength and elasticity of frankfurters. To determine the skin strength a load was applied at a rate of 0.5 in /min to the surface of the frankfurters by means of a 1/4-in diameter rod which produced a puncture. This procedure was applied to three or four surface areas on each of three samples from each lot.

The elasticity of three frankfurters from each lot was measured by placing a frankfurter in a compression cage. A load was applied which compressed the frankfurters at a rate of 0.2 in /min to produce compression of 0.3 in. Compression was reduced also at a rate of 0.2 in /min until zero load was attained. The areas were measured by an integrator. The data are reported as a ratio between the energy recovered after deformation and the energy expended in compression.

RESULTS & DISCUSSION

FORMULAS used in preparing frankfurters containing either 25% or 35% beef fat, pork fat, or cottonseed oil and results of analyses of finished products are shown in Table 1. Results show there were only small differences in content of fat, protein and moisture of frankfurters formulated so as to be of comparable composition. Percentages of added moisture (moisture, % – 4 x protein, %) ranged from 2.4–8.4, and were somewhat lower than those sought in commercial production.

Table 2 shows the rpm used in comminution, the maximum temperature attained by each lot of emulsion comprising each series, data on shrinkage, specific gravity, and results of examinations conducted to detect "fat-caps" and determine peeling scores. The discussions which follow refer to data in Table 2 with exceptions as noted.

The curves in Figure 1 show the time required for emulsions to attain temperatures ranging from 45°–85°F; the measurements were begun after ice, curing agents and spices, and fats, or oil, had been added. Examination of the curves shows that time for chopping was highly dependent upon the rpm used. Points on the curves, particularly those shown for chopping at 2500 or 5000 rpm, indicate temperature rise was similar in chopping emulsions containing either of the fats or the oil. Calculations based on the curves indicate that temperatures increased at maximum rates of approximately 1.7°, 4.1°, and 11.4°F/min in chopping at 1500, 2500, and 5000 rpm, respectively. An indication of the practical importance of high rpm is that the time required to attain 60°F, a typical temperature in commercial operations, was reduced by approximately 50% on increasing rpm to each next higher rate.

The average and range of viscosity values obtained with Brookfield equipment on emulsions comminuted to temperatures in the range studied are shown in Figure 2. Data on emulsions containing 25% or 35% of the fats, or the oil, and comminuted at different rpm are combined since varying fat level or rpm in chopping did not produce statistically significant differences; it is to be noted, however, that replications were limited and these data do not indicate that the variables did not affect viscosity to some extent. The results indicate that at 45°F emulsions containing beef or pork fat had higher viscosities than those containing cottonseed oil ($P < 0.05$), probably because the tissue fats were largely unmelted. At higher temperatures viscosities decreased as chopping and temperatures increased, the viscosities of emulsions prepared with beef fat or cottonseed oil being relatively high and approximately equal and those of emulsions prepared with pork fat somewhat lower. The tendency for viscosity to decrease during chopping contrasts with the increasing viscosity of meat protein stabilized model o/w emulsions as emulsification progresses (Swift et al., 1961); the explanation may be that any effect of fat emulsification was masked by the viscosity of lean portions swollen and viscous after the action of curing agents and water (Hamm, 1960), and that the decreasing viscosity resulted from a continued mincing of the lean portion. A similar masking may also have been responsible for the fact that the viscosity values were not closely related to emulsion stability. Lack of a direct relationship is shown by the fact that the viscosity of emulsions prepared with beef fat and those prepared with cottonseed oil and chopped to 55°F were relatively high and approximately equal; in the smokehouse, "fat-caps" formed in those

Processing

The emulsions were prepared in a 90-lb capacity Model KA 110 Koch-Alpina silent cutter fitted with six knives which were operated at 1500, 2500, or 5000 rpm, with bowl speeds of 6.5, 13, or 22 rpm, respectively, depending on the current level and/or the pulley ratio selected. The cutter was fitted with a thermocouple and emulsion temperatures were continuously recorded tc within ± 2°F. All ingredients, except fats or oil, were placed in the silent cutter and the machine operated for 1-1/2 to 2 min at reduced speed, except that in comminuting at 1500 rpm this rate was maintained throughout. The tissue fats, or the oil, were then added and the machine was operated at the selected maximum rate.

Samples weighing approximately 11 lb each were removed when the emulsions became 45°, 55°, 65°F and higher temperatures, in some cases as high as 85°F. Elapsed time was recorded. Small portions of these samples were used in determining viscosity. Small portions of emulsions were vacuumed: both vacuumed and non-vacuumed were stuffed into 23 mm No-Jax casings. Hereinafter the samples withdrawn and stuffed by the above described procedure are termed lots (designated by temperature of sampling) which make up series (designated by level and type of fat or oil and the rpm during comminution).

The lots of frankfurters were weighed and then cooked and smoked in an air-conditioned smokehouse operated to produce 130°F DB for 10 min; 145°F DB-135°F WB for 30 min; 165°F DB-140°F WB for 12 min, and 190°F DB-163°F WB until, in approximately 10 min, internal temperatures became 155°–157°F. Internal temperatures were determined by means of thermocouples inserted when the frankfurters became sufficiently heat coagulated. The frankfurters were showered with cold water until internal temperatures decreased to 90°F and were held in the smokehouse an additional 10 min to dry. They were weighed and stored overnight at 37°–39°F in plastic tubs covered with polyethylene film. After an examination during which "fat-caps" and the relative ease of peeling were observed the frankfurters were vacuum packaged in Kapak pouches; those containing samples intended for determinations of specific gravity and texture were stored at 37°–39°F, and those for histological examination at 0°F.

Methods

The percentages of moisture, fat, and protein in meat raw materials and finished frankfurters were determined by A.O.A.C. methods (A.O.A.C., 1965). The mean apparent viscosity of each lot of emulsion was determined immediately upon withdrawal from the chopping bowl from duplicate measurements with a Model HBT Brookfield viscosimeter mounted on a Helipath stand (designed for use with plastic and thixotropic materials) and equipped with a special bar-type spindle (shaft length, 11.5 cm; shaft diameter, 3 mm; cross bar length, 25.8 mm; cross bar diameter, 1.5 mm; rotation at 50 rpm in air).

From the data on weights of lots before and after cooking and smoking the percentage of shrinkage of each lot and the mean percentage of shrinkage of each series were calculated. The presence of any "fat-caps" and the relative ease of peeling were determined by examining 55–65 frankfurters from each lot. Judgments were made on manually removing casings rang-

Table 2—Effects of different levels and types of fat and rates and temperatures of comminution on the production of frankfurters.

Series no.	Fat content %	Emulsification: Rpm	Emulsification: Temp. °F	Smoking-cooking: Shrinkage[1] %	Smoking-cooking: Fat separation[2,3]	Peel-ability[2,4]	Specific gravity[5]
			Beef fat				
1	25	1500	45		++	G–	0.949 a
			55	10.2 ± 0.2	++	G–	0.973 b
			65		0	G (W)	0.993 c
			71		0	G (W)	1.000 c
2	35	1500	45		++	G +	0.963 a
			55	7.8 ± 0.3	++	G +	0.970 b
			65		0	G +	1.006 c
			70		0	G +	1.003 c
3	25	2500	45		++	G +	0.951 a
			55		++	G +	0.967 b
			65	10.7 ± 0.1	++	G +	0.980 b c
			75		0	G +	0.990 c
			82		++	G +	1.005 d
4	35	2500	45		++	E	0.935 a
			55		++	E	0.954 b
			65	9.2 ± 0.3	+	G +	0.970 c
			75		0	G +	1.000 c
			83		+++	P	1.007 c
5	25	5000	45		++	E	0.970 a
			55		+	E	0.974 a
			65	10.1 ± 0.2	+	G +	0.994 b
			75		0	G +	1.003 b c
			85		0	P	1.005 c
6	35	5000	45		++	G +	0.953 a
			55		+	G +	0.960 b
			65	8.8 ± 0.2	+	G –	0.964 c
			75		0	G (W)	0.997 d
			85		0	G (W)	1.002 d
			Pork fat				
7	25	1500	45		0	G +	0.973 a
			55	9.7 ± 0.1	0	G +	0.972 a
			65		0	G +	1.007 b
			69		0	G +	1.008 b
8	35	1500	45		++	G –	0.961 a
			55	7.8 ± 0.4	0	G +	0.970 b
			65		0	G +	1.002 c
			72		0	G +	1.004 c
9	25	2500	55		0	G +	0.968 a
			65	9.0 ± 1.0	0	G +	0.999 b
			75		0	G +	1.014 b
			79		0	P	1.015 b
10	35	2500	55		0	G +	0.948 a
			65	6.4 ± 0.6	0	G +	0.983 b
			75		0	G +	0.996 c
			78		0	P	1.003 d
11	25	5000	55		0	G –	0.959 a
			65	9.6 ± 0.2	0	G +	0.987 b
			75		0	G +	0.999 b c
			85		0	G +	1.007 c
12	35	5000	55		0	G +	0.964 a
			65	7.5 ± 0.7	0	G +	0.971 [illegible]
			75		0	G +	1.005 c
			85		0	G +	1.001 c

(continued)

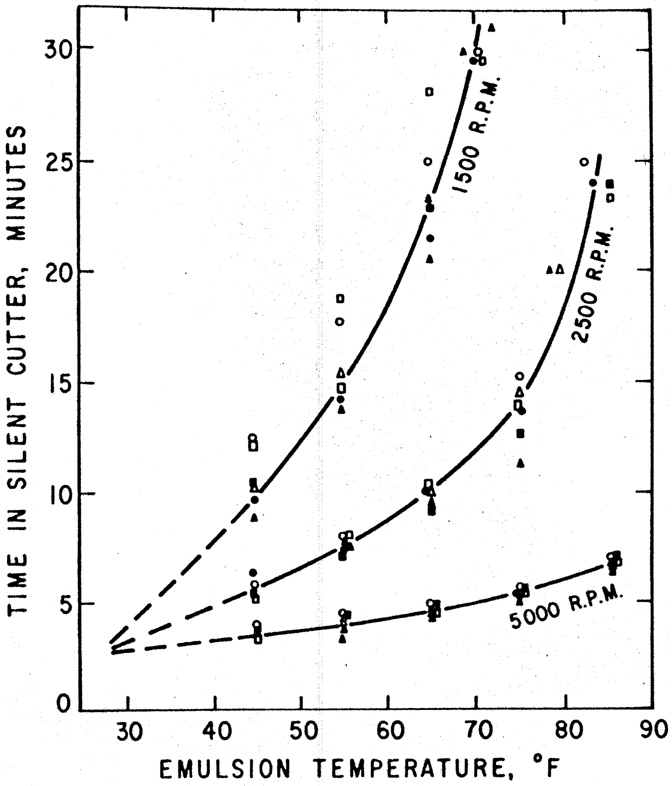

Fig. 1—Time required to attain temperatures from 45°–85°F in comminuting at 1500, 2500, or 5000 rpm. 25% beef fat (○); 35% beef fat (●); 25% pork fat (△); 35% pork fat (▲); 25% cottonseed oil (□); 35% cottonseed oil (■).

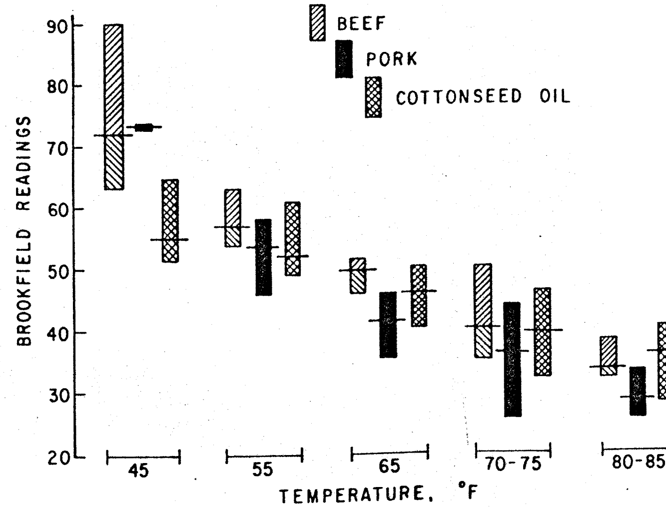

Fig. 2—Range and average of Brookfield readings on emulsions prepared with beef or pork fats, or cottonseed oil at temperatures attained during comminution.

prepared with beef fat but not in those prepared with cottonseed oil (Table 2). Other evidence is that little variation existed among the low viscosities of emulsions prepared with beef fat and chopped to 80°–85°F, although "fat-caps" formed on two of the four in the smokehouse. Based on these results, determination or control of emulsion viscosity cannot substitute for, or be a valuable addition to, control of time and/or temperature in assuring emulsion stability.

The mean percentage of shrinkage in cooking and smoking each series is shown. Results indicate that shrinkage was affected by the level and type of fat in the frankfurters, but not the rpm used in chopping emulsions. Increasing shrinkage correlated with decreasing content of fat in frankfurters prepared with beef or pork fat ($r = -0.83$, $P < 0.01$) and those prepared with cottonseed oil ($r = -0.96$, $P < 0.01$); the shrinkage of the latter frankfurters was the largest.

Data are given on the incidence of fat separation in the form of "fat-caps" among the lots of frankfurters. "Fat-caps" principally formed on frankfurters containing beef fat and, most frequently, those prepared from underchopped emulsions. Otherwise, only the appearance of "fat-caps" on frankfurters prepared from emulsions chopped to 45°F at 1500 rpm containing 35% pork fat, or 35% cottonseed oil (if not added in portions), was an indication of underchopping. The results suggest that the dispersion of beef fat was slowed by the relatively high temperature required to produce sufficient melting. The data show that emulsions chopped slowly (25 min at 1500 rpm) were stable on chopping only to 65°F, while, in chopping at 2500 or 5000 rpm, 75°F was required to attain stability. This indication that optimum temperature increased with increased rpm of chopping probably signifies that a combination of time and temperature affected melting of fat and, as a consequence, its dispersion. The existence of a relationship of time and temperature has been previously recognized, presumably as the result of observations in commercial sausage making (MacKenzie, 1966).

Table 3—Relation of skin strength and maximum temperature attained during comminution.

Series No.	Fat Type[1]	Fat Content %	Emulsification Rpm	Number of samples	Regression of skin strength on temp (°F)	Correlation coefficient	F test[2]
1	BF	25	1500	38	2.235–0.0121T	0.70	36.2**
2	BF	35	1500	37	2.313–0.0166T	0.72	39.8**
3	BF	25	2500	38	2.103–0.0066T	0.35	5.3*
4	BF	35	2500	38	1.454–0.0007T	0.04	0.08 N.S.
5	BF	25	5000	38	2.009–0.0081T	0.59	19.5**
6	BF	35	5000	38	2.150–0.0144T	0.88	125.0**
7	PF	25	1500	38	2.134–0.0148T	0.71	39.4**
8	PF	35	1500	28	2.753–0.0223T	0.72	29.9**
9	PF	25	2500	28	1.673–0.0043T	0.33	3.4 N.S.
10	PF	35	2500	36	1.457–0.0065T	0.66	27.0**
11	PF	25	5000	38	1.445–0.0058T	0.46	10.0**
12	PF	35	5000	38	1.333–0.0057T	0.68	33.1**
13	CO	25	1500	38	2.454–0.0170T	0.80	66.9**
14	CO	35	1500	38	1.683–0.0035T	0.22	2.0 N.S.
15	CO	25	2500	38	1.973–0.0085T	0.52	13.9**
16	CO	35	2500	38	1.445–0.0045T	0.36	5.5*
17	CO	25	5000	48	1.643–0.0020T	0.18	1.5 N.S.
18	CO	35	5000	48	1.268–0.0005T	0.05	0.1 N.S.

[1] Beef fat, pork fat, and cottonseed oil are indicated by BF, PF, and CO, respectively.
[2] N.S. – Not significant at 5% level of probability.
*$P < 0.05$; **$P < 0.01$.

Overchopping was produced only by chopping emulsions containing beef fat for long periods to high temperatures. The lengthy comminution (over 30 min) required to attain 71°F did not affect the stability of emulsions comminuted at 1500 rpm, nor did rapid comminution (ca. 7 min) at 5000 rpm to produce temperatures of 85°F. "Fat-caps" formed, however, on frankfurters prepared from emulsions comminuted 24 or 25 min at 2500 rpm to temperatures of 82° or 83°F. These results indicate that in overchopping a limit involving a time-temperature relationship was exceeded. In addition, since emulsions containing pork fat or cottonseed oil chopped under the same conditions were stable, the results indicate that one or more characteristics of beef fat produced problems in emulsification.

The relative ease with which casings could be removed from the lots of frankfurters is reported. Peeling was scored as poor in removing casings from five lots of frankfurters, two each among frankfurters containing the different fats and one containing the cottonseed oil. All had been prepared from emulsions chopped to 78°F or above. "Fat-caps" had formed on only one. Although peeling scores on other lots which had been chopped to high temperatures were rated as good, the results suggest that chopping to high temperatures was responsible for poor peeling when it occurred, possibly owing to a lack of the surface greasiness which has been reported to be a factor (Saffle et al., 1964).

Results of specific gravity determinations of frankfurters from all lots are shown in Table 2. The data indicate that the specific gravity became 1.000 or higher in frankfurters prepared from emulsions chopped to the highest temperatures attained. This required a reduction of approximately one-half the air present in frankfurters prepared from emulsions chopped to 45° or 55°F (frankfurters prepared from vaccum-treated emulsions ranged from 1.04–1.05). It is reasonable to assume that, as temperature increased, air became less soluble.

The effect of skin strength (puncture test) of chopping emulsions to increasing temperatures is shown in Table 3 by regression equations. Equations for each series indicate that increasing the time-temperature of chopping tended to decrease skin strength: 13 of 18 relationships being significant at the 95%, or higher, level of confidence. It has been reported that skin strength is developed by a migration of protein to the surface of frankfurters and subsequent denaturation during smoking (Saffle et al., 1964). Assuming this mechanism to be the source of skin strength, migration in frankfurters prepared from emulsions chopped to 45° or 55°F, including some lots on which "fat-caps" formed, was greater than in frankfurters prepared from emulsions chopped at higher temperatures. A possible explanation of decreased protein migration could be that proteins were increasingly utilized in membrane formation as chopping proceeded to higher temperatures and were insoluble.

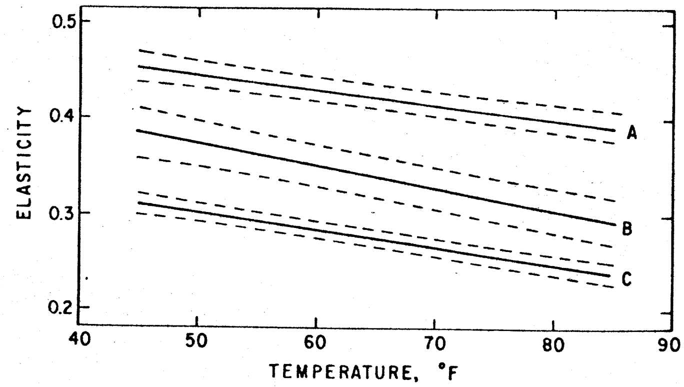

Fig. 3—Elasticity of frankfurters prepared from emulsions containing cottonseed oil (A), pork fat (B), or beef fat (C) and chopped to different temperatures. Values indicate recovered/expended energy applied during compression. 95% confidence limits calculated on means are shown.

Regression lines of mean values of elasticity on temperature are shown in Figure 3. Analyses showed that differences in the elasticity of frankfurters prepared with 25% or 35% of the fats, or the oil, and chopped at different rpm were not statistically significant and the data were pooled. The results show that the elasticity of frankfurters decreased in the order cottonseed oil, pork fat and beef fat. In informal tasting, frankfurters prepared with cottonseed oil were found to have a fine, unfamiliar and poor texture. Its relatively high elasticity can be equated to rubberiness, since a perfectly elastic system would have an elasticity of one on the scale shown in Figure 3. Increasing time and temperature of chopping decreased elasticity to a degree, but elasticity primarily depended on the lipid present. Differences in the dispersion of the fats, or the oil, during chopping could account for the observed differences. A second paper will consider such evidence.

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Ms. received 6/2/70; revised 8/27/70; accepted 8/27/70.

Grateful acknowledgement is made to Brian S. Blinkoff for measurements with the Instron instrument and to Virginia G. Martin for applying statistical treatments.

Mention of commercial names does not imply endorsement by the U.S. Department of Agriculture.